The Impact of Mega-Catastrophes on Insurers: An Exposure-Based Analysis of the U.S. Homeowners' Insurance Market

Bjoern Hagendorff, Jens Hagendorff* and Kevin Keasey

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ABSTRACT

Insurance is a key risk sharing mechanism that protects citizens and governments from the losses caused by natural catastrophes. Given the increase in the frequency and intensity of natural catastrophes over recent years, this paper analyzes the performance effects of mega-catastrophes for U.S. insurance firms using a measure of market expectations. Specifically, we analyze the share price losses of insurance firms in response to catastrophe events to ascertain whether mega-catastrophes significantly damage the performance of insurers and whether different types of mega-catastrophes have different impacts. The main message from our analysis is that the impact of mega-catastrophes on insurers has not been too damaging. While the exact impact of catastrophes depends on the nature of the event and the degree of competition within the relevant insurance market (less competition allows insurers to recoup catastrophe losses through adjustments to premiums), our overall results suggest that U.S. insurance firms can adequately manage the risks and costs of mega-catastrophes. From a public policy perspective, our results show that insurance provides a robust means of sharing catastrophe losses to help reduce the financial consequences of a catastrophe event.

Key words: Catastrophe risk, Homeowners' insurance, Performance

* Corresponding author. Bjoern Hagendorff and Kevin Keasey are at the University of Leeds, Maurice Keyworth Building, LS2 9JT, UK. Jens Hagendorff is at the University of Edinburgh, 29 Buccleuch Place, Edinburgh EH8 8JS, UK. E-mail addresses: bn08bh@leeds.ac.uk (B Hagendorff), jens.hagendorff@ed.ac.uk (J Hagendorff), kk@lubs.leeds.ac.uk (K Keasey).

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1 INTRODUCTION

Governments within developed economies depend, to varying degrees, on insurance firms to protect their citizens from the losses associated with natural catastrophes. In the absence of insurance, catastrophe losses are likely to cause severe hardship and falls in the living standards of affected households. In the U.S. and a number of other countries (for example, Mexico, Chile, France, Germany, Japan and the UK), governments partly assume responsibility for some catastrophe risks in regions where these risks are high and, therefore, deemed uninsurable.(1) For instance, governments may choose to partly reimburse citizens for catastrophe losses where citizens are insufficiently insured. However, where governments act as backstops for catastrophe losses, this can have adverse effects on public finances if large perils trigger substantial payouts to citizens.

Therefore, next to protecting citizens, catastrophe insurance also protects governments from the losses linked to natural perils. Further, the risk sharing provided by insurance is potentially efficient in that it offers incentives to the insured to reduce the economic losses linked to natural perils ex ante. For instance, insurance contracts can limit economic losses by rewarding well-designed buildings with lower premiums, lower deductibles and higher coverage limits on insurance policies.(2) Given the importance of insurance as a robust and efficient risk sharing mechanism, questions over the extent to which insurers can manage the risks and costs of catastrophe losses are issues of great importance from a public policy perspective.

In recent years, there has been a remarkable increase in the frequency and severity of natural catastrophes; for instance, the economic losses from natural catastrophes increased from $528 billion (1981-1990) to $1.6 trillion over the period 2001-2011.(3) Out of the 25 most costly catastrophes (in terms of inflation-adjusted insured losses) between 1970 and 2009, 14 have occurred since 2001.(4)

One cause for concern is how far insurance firms have been able to cope with the significant increase in underwriting losses from catastrophe events in recent years. Mega-catastrophes, such as Hurricane Katrina in 2005 or the recent earthquake and tsunami in

Japan, are high-severity and low-frequency events which can be particularly costly to insurance firms. The high-severity nature of mega-catastrophes causes large underwriting losses, while the low frequency nature of mega-catastrophes means they are difficult to predict and incorporate into the premium pricing for catastrophe coverage. Therefore, the performance implications of mega-catastrophes on insurance firms should be a concern for both governments and citizens.[(5)]

Given the above concern, the purpose of this study is to analyse two related research questions. First, do mega-catastrophes significantly damage the performance of insurance firms? Second, do different types of mega-catastrophe have different impacts on insurance firm performance? These questions are addressed by analysing the expected performance implications of mega-catastrophes on U.S. property-liability (P&L) insurance firms. More specifically, by using detailed data on homeowners' insurance coverage by state, firm and year, we compute the market revaluation effects realized by P&L insurers with risk exposure to mega-catastrophes in response to 19 U.S. mega-catastrophes. Our sample of insurers is substantial and includes the near population of publicly traded U.S. P&L insurers with loss exposure to homeowner's business during 1996 to 2010.

Addressing the first research question, we demonstrate that across the series of 19 U.S. mega-catastrophes, shareholders in U.S. P&L insurers realize wealth losses on average. However, the relatively small magnitude of these wealth losses suggests that the expected performance effects of mega-catastrophes are by no means devastating. Since the value losses we report are of moderate order, our results paint a cautiously optimistic picture in terms of the ability of insurers to manage the risks and costs of catastrophe losses. Insurance, therefore, appears a robust instrument for sharing catastrophe losses.

Moving onto the second research question, the analysis shows that the equity revaluation effects vary significantly across the different types of catastrophe. More specifically, the analysis shows that hurricanes have less negative value implications for insurers than other catastrophe events. This is particularly reassuring, because hurricanes have historically been the most devastating peril in the U.S. and risk sharing via insurance firms is particularly important for hurricanes. Furthermore, catastrophes that occurred after Hurricane Katrina in 2005 receive a less negative market reaction than catastrophes that occurred pre-Katrina. The latter finding is in line with explanations that Hurricane Katrina caused the insurance industry to upwardly revise its expectations of the potential magnitude and frequency of mega-catastrophes. Put differently, post-Katrina, the insured losses caused by mega-catastrophes have been better anticipated by insurers and have been reflected in the premium income of P&L insurers.

Recent empirical work emphasizes the need for government-assisted insurance to supplement private insurance arrangements where weather-related natural disasters cannot be insured by private insurance alone.[1, 4, 6, 7] This literature sees a continued role for governments in the provision of insurance to households in partnership with private insurers and acknowledges that more needs to be done to understand the ability of private insurance to cope with increasing catastrophe losses. Our paper contributes to this literature by analyzing how robust a risk sharing mechanism private insurance is when it comes to underwriting catastrophe risk. Overall, our analysis shows that U.S. insurance firms have coped remarkably well with the increasing frequency and severity of mega-catastrophes, and have adjusted their business model post Hurricane Katrina.

From a public policy perspective, our results show that insurance appears to provide a robust mechanism for sharing catastrophe losses and can form part of comprehensive national strategies to deal with catastrophes. Insurance can help deal with some of the financial consequences of a natural catastrophe. However, it needs to be realized that any financial coverage should only ever be part of an overall national strategy for dealing with the increasing risks and losses associated with catastrophes. More specifically, insurance solutions need to be seen as complements to risk assessment, risk perception, risk prevention and risk mitigation, and this also applies to humanitarian relief in the immediate aftermath of a catastrophe event (such as that provided by the Federal Emergency Management Agency). Nonetheless, the evidence presented here shows that the catastrophe insurance provided by the private sector can form a meaningful part of broader national strategies to deal with the increasing threats and costs of catastrophe.

The remainder of the paper is organized as follows. The next section discusses the data and empirical strategy employed to gauge changes in the value of insurers in response to mega-catastrophes. Sections 3 and 4 present the results of the univariate and multivariate analysis, respectively, and Section 5 offers conclusions.

2 DATA AND METHODOLOGY

2.1 Data

We use two main types of data to analyze the impact of mega-catastrophes on the performance of publicly traded P&L insurers during the period from 1996 to 2010: data on the magnitude and geographic spread of mega-catastrophes as well as financial data on P&L insurers.

To collect data on mega-catastrophes, we obtain statistics on insured property losses from Property Claims Service (PCS). The data include information about the date, value of first insured loss estimates, and the states affected by catastrophe events that cause $25 million or more in direct insured losses to property.[*] PCS uses surveys of insurers, agents, adjusters, public officials, and others to gather data on claim volumes and loss estimates. The data cover insurance payments for property lines of insurance including, fixed property, building contents, time-element losses, vehicles, and inland marine (diverse goods and properties).

Since our study focuses on U.S. homeowners' exposure, we restrict our sample of catastrophe events to natural catastrophes, i.e. events which are caused by natural forces. Terrorism attacks or man-made disasters (such as aviation accidents and explosions) are not included in our sample, because these disasters are more likely to impact on commercial (rather than homeowners') lines and because these disasters only affect a small number of policies. Further, we only include catastrophe events with first insured loss estimates in excess of $1 billion and we call these events mega-catastrophes.[†]

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[*] The threshold of $25 million of insured losses applies to the total event, i.e. insured losses at the state level can be (much) smaller than $25 million.

[†] First insured loss estimates are adjusted for inflation using the All Urban Consumer Price Index for the United States (CPI-U) for a base year 2010.

From an initial sample of 24 mega-catastrophes, we exclude five catastrophes to avoid overlaps in the examination period of up to 20 trading days after the event occurred.[*] Our final sample, therefore, consists of 19 mega-catastrophes which can be broken down into 191 state-level catastrophes, which in turn make it an ideal landscape for research.[†] Our sample covers more than $80 billion in first insured loss estimates (which corresponds to nearly 40 percent of total first insured loss estimates) during 1996 to 2010 according to the PCS data.[‡]

Table I provides descriptive statistics on the mega-catastrophes we include in our analysis.

[Table I near here]

The data presented in Panel A include the catastrophe date, the peril type (hurricane, storm, etc.), the affected states as well as first insured loss estimates for all 19 sample mega-catastrophes. Panel B presents the number of mega-catastrophes broken down by state. With a total of nine events, hurricanes make up the majority of our sample of mega-catastrophes. Further, Florida and Massachusetts are the states most frequently hit by mega-catastrophes in our sample (i.e. 11 times each).

To build our sample of publicly traded P&L insurers in the U.S., we first download a list of firms which both the Center for Research in Security Prices (CRSP) and Datastream classify as P&L insurers (based on a SIC code of 6330 or 6331). This yields an initial sample of 142 publicly traded P&L insurers. In cases where only one database identifies a firm as a P&L insurer, we check the firm's website to confirm its specialization. This way, we can identify an additional 26 P&L insurers.

[*] The omitted mega-catastrophes are Hurricane France (04.09.2004), Hurricanes Jeanne and Ivan (both 15.09.2004), as well as Hurricane Gustav (31.08.2008) and Hurricane Ike (12.09.2008).

[†] We obtain the number of state-level catastrophes by summing up the number of states which are affected by a mega-catastrophe. For example, if a hurricane affects four states, we count four state-level catastrophes.

[‡] The PCS database holds records on 414 individual natural catastrophe events during the period 1996 to 2010 which have caused total first insured loss estimates of nearly $215 billion.

We then match the sample of P&L insurers with data on premium earnings compiled from the State Pages of insurers' annual filings with the National Association of Insurance Commissioners (NAIC). The NAIC filings provide detailed state-level data on the composition of an insurer's premium income. To ensure that sample firms are P&L insurers with at least some relevant risk exposure to mega-catastrophes, we only include insurers in the sample if the NAIC filings show that insurers have homeowners' loss exposure at the time of a mega-catastrophe. That is, insurers need to have positive premiums *earned* in the homeowners' line in the year the catastrophe occurred.[*] Finally, we require sample firms to have accounting and share price information on COMPUSTAT and CRSP, respectively. Our final sample consists of 57 publicly traded P&L firms. A list of our sample of insurers is provided in Appendix Table A2.

2.2 Methodology

To estimate the impact of mega-catastrophes on insurance firms' stock price performance during the period 1996 to 2010, we use market-adjusted abnormal returns[†] (AR) as employed by others: [8, 9]

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[*] As insurance premiums are usually paid in advance, it is common to classify premiums into premiums written and premiums earned. While premiums written are equal to the revenues from insurance policies sold in a given period, earned premiums are equal to the portion of premiums written which is actually exposed to loss. For example, if an annual policy begins on July 1, the written premium is equal to the total revenue of that policy (usually the price of the policy), while premiums earned would only make up half the policy's total revenue. Since we are interested in the actual loss exposure of individual insurers, we use earned premiums as in other studies.[10]

[†] We do not estimate market model-adjusted returns (which yield risk-adjusted returns) for two reasons. First, the market model approach assumes that the estimation period over which market model parameters are estimated is free of the type of event whose value effects are being investigated. If we were to compute risk-adjusted abnormal returns using contaminated estimation periods, the resulting estimates would be unreliable. Since our sample of insurers contains firms that are hit by more than a single mega-catastrophe in close succession, we do not have the clean time series of return data necessary to implement this approach. Second, over short-time periods risk-adjusted return values do not significantly improve estimation results as compared to the type of market-adjusted values we employ in this study.

$$AR_{it} = r_{it} - r_{mt} \tag{1}$$

where r_{it} is the return for insurer i on day t and r_{mt} is the CRSP equally-weighted market index return for day t.* Equity return data are from CRSP. We average AR across days and firms to yield cumulative abnormal returns (CAR). To test for the statistical significance of cumulative abnormal returns, we employ a two tailed t-test as well as the non-parametric Mann-Whitney-Wilcoxon test which is robust to the effects of outliers. With the exception of hurricanes, we define the event date as the trading day on which the mega-catastrophe took place (if the event occurs on a non-trading day, we use the next trading day instead). For hurricanes, we use the first trading day during the two calendar days before the event date.† This is because hurricanes can be tracked with a fair amount of accuracy and, consequently, we expect some information leakage prior to the hurricane hitting land.

3 UNIVARIATE RESULTS

3.1 The Shareholder Wealth Effects of Mega-catastrophes

In this subsection we examine changes in the market value of P&L insurers in response to mega-catastrophes. Table II reports insurers' market adjusted abnormal returns linked to our sample of mega-catastrophes for selected event windows. Thus, for all event windows after the catastrophe event date, cumulative abnormal returns (CAR) are negative and statistically significant at the 1%-level (for both t-tests and z-tests), ranging from -0.279 percent on day one to -1.393 percent 20 days after the event date. Based on the

* We use the CRSP-equally-weighted market index for market returns. This return index is more dominated by returns on smaller firms (relative to a value-weighted index). This is appropriate for our sample of small and medium sized P&L insurers (the median sample firm is smaller than the median firm included in the CRSP indices). Further, numerous previous studies on the performance implications of catastrophe events for insurers have also employed the CRSP-equally-weighted index.[11-13]

† For example, if the hurricane occurs on a Monday, our set-up assumes that the event could have been forecast since Saturday. As Saturday is not a trading day (and no market reaction can be observed that day), we use Monday as the first day of the analysis in this case.

results, we conclude that the prospect of potentially substantial loss reimbursements to policyholders outweigh any expected benefits of potential premium increases in the aftermath of a catastrophe event.

[Table II near here]

However, Table II also shows that the sample is nearly split equally in half as regards firm observations experiencing value gains and value losses from mega-catastrophes and there is heterogeneity in the market valuation effects linked to mega-catastrophes. The next subsections, therefore, identify some of the factors which determine the market reaction to catastrophe events.

3.2 Value Effects and Insurers' Loss Exposure

In this subsection we investigate how an insurer's loss exposure impacts upon changes in the insurer market value in response to a mega-catastrophe. It is important to understand to what extent loss exposure can explain our results. For instance, the relatively modest value losses for insurers we report above could be driven by insurers with little or no exposure to mega catastrophes. These unexposed insurers may benefit from additional insurance demand following a catastrophe event without having to indemnify existing policyholders for insured losses. We capture loss exposure using the homeowners' premium income earned in the states affected by a mega-catastrophe.

Figure 1 presents a graphical comparison of cumulative abnormal returns (CAR) for both unexposed and exposed insurers up to 20 days following a mega-catastrophe. We classify firms as either exposed or unexposed based on whether or not they have positive premiums earned in the homeowners' line of business in any affected state(s). Two important conclusions can be drawn from Figure 1. First, mega-catastrophes have different performance implications for exposed and unexposed insurers. While exposed insurers experience negative CAR throughout the 20 days following a mega-catastrophe, CAR for unexposed insurers becomes positive 11 days after the catastrophe event. Second, Figure 1 provides graphical evidence of a delay in the market response to mega-catastrophes. The return difference between exposed and unexposed insurers widens around 10 days after the catastrophe event. A delay in the market response may be attributable to a lack of data on expected loss estimates [(14)], the degree to which damaged property was insured or due to effects on the demand for insurance.

[Figure 1 near here]

To more formally test these propositions, Table A.III in the Appendix reports CAR for different event windows following mega-catastrophes by whether or not insurers had loss exposure (Panel A). In addition, the level of loss exposure (defined as the ratio of direct earned homeowner premiums in the affected states to nationwide direct earned homeowner premiums in the year the catastrophe struck) is examined in Panel B.

Table A.III reports three important findings. First, and in line with Figure 1, it shows that insurers exposed to catastrophes suffer value losses, while insurers with no earned premium in the affected states (unexposed insurers) are not affected by mega-catastrophes. Second, it also shows that a higher level of loss exposure negatively impacts upon the stock price performance of insurers. Finally, it confirms that insurers' wealth losses in response to mega-catastrophes are rather modest, indicating that mega-catastrophes do not have devastating performance effects on insurers. Thus, on average, even insurers located in the highest quartile (Q_4) of the distribution of loss exposure experience share price losses of less than 5 percent during the event period (Panel B), while the share price losses for the subsample of exposed insurers is less than 2 percent (Panel A).

3.3 Value Effects and Competition in the Homeowners' Insurance Market

An additional factor that may influence an insurer's stock price reaction is the level of competition at the state level in the homeowners' insurance market. Insurers are likely to face more difficulty in raising premiums when operating in highly competitive states as compared to insurers operating in states with little competition in the homeowners' insurance market. More specifically, it could be argued that premium increases after a mega-catastrophe will be smaller in highly competitive states (which will make it more difficult to offset initial reimbursements paid to policyholders and capital depletions) as compared to states with low levels of competition, because premium increases in more competitive states are likely to result in a permanent loss of market share. Therefore, it is conceivable that our result of relatively modest value losses for insurance firms around catastrophe losses may be partly caused by the competition levels prevailing in different states. For instance, if the insurance firms most affected by mega catastrophes are operating in states with low levels of competition (and a high prospect of premium increases after the event), this could go some way to explaining why our results show that the value losses of catastrophes for insurance firms are not too devastating.

We calculate a measure of competition in two steps. In a first step, we calculate the sum of the squared percentages of homeowners' insurance premiums earned (relative to the total homeowners' insurance premium earned by all insurers) for each state and year. The resulting Herfindahl index measures the concentration of premium income (or lack of competition) in the homeowners' insurance market in each state. In a second step, we calculate the average Herfindahl index across the states in which an insurer operates by weighting the Herfindahl index by the proportion of homeowners' insurance premiums earned in each state relative to the nationwide total of direct homeowner premiums. Since the resulting Herfindahl index captures the lack of competition across the states in which an insurer operates, we compute 1-Herfindahl index to yield a measure of competition. The competition measure ranges from 0 to 1, with higher values indicating increased competition for an insurer.

Table A.IV in the Appendix reports market-adjusted cumulative abnormal returns for different event windows after a mega-catastrophe for the highest (Q_4) and lowest quartile (Q_1) of the distribution of the competition measure and shows the differences in abnormal returns between the highest and lowest quartile ($\Delta CAR_{HIGH\text{-}LOW}$). For the sample as a whole, as well as for the subsample of exposed insurers (Panel B), the results show that the value losses are greater when insurers predominantly operate in the most competitive states as compared to insurers operating in the least competitive states. Further, we find that unexposed insurers (Panel C) benefit from mega-catastrophes if they write business in the least competitive states.

Overall, the results in this sub-section show competition amongst insurers conditions their business responses to mega-catastrophes. Most importantly, even in the most competitive states, where insurance firms should find it most challenging to increase premiums following a catastrophe event, the value losses causes by mega catastrophes remain of a modest order. This confirms our main finding that the damage which market investors believe mega catastrophes inflict on insurance firms is modest and it demonstrates that insurance is a robust sharing mechanism for catastrophe risk.

4 MULTIVARIATE RESULTS

4.1 The Model

Next, we use multivariate regression analyses to assess the robustness of our findings in the univariate analysis and to jointly estimate the various factors which affect the market reaction of insurers to mega-catastrophes. Specifically, we estimate the following model via OLS with robust standard errors.

$$\mathbf{CAR}[0,+15] = \alpha+\gamma'\mathbf{IC}+\theta'\mathbf{CC}+\varepsilon \tag{2}$$

where **CAR**[0,+15] is the market-adjusted mean cumulative abnormal return over [0,+15] days relative to the catastrophe event date, **IC** is a vector of insurer characteristics in the fiscal quarter before the catastrophe event, and **CC** is a vector of catastrophe event characteristics.

[Table III near here]

We use a multi-week event window as in previous studies.[11, 15] We require a multi-week event window to ensure that our event window coincides with the disclosure of important information about a catastrophe event to market investors. The PCS catastrophe database we use shows that, on average, a catastrophe lasts for 3 to 4 days and that it takes another 9 to 10 days before the first estimate of insured losses are published. Figure 1 and Table A.III in the Appendix confirm that it takes around ten days for a more substantial market response to a mega-catastrophe to materialize. Finally, to control for the effect of unobserved variables that are constant over years and insurers, we also include firm and year fixed effects into our model.

Table III includes descriptions and summary statistics for the vector of insurer characteristic and control variables. All accounting data (unless stated differently) refer to one fiscal quarter prior to the catastrophe event date and are from COMPUSTAT. Premium income data refer to the current fiscal year of the catastrophe event and are from NAIC insurer filings. Loss estimates are from the PCS database.

4.2 Regression Results

This sub section presents the results of the regressions on market-adjusted cumulative abnormal returns (CAR[0,+15]) in response to mega-catastrophes. The results shown in Table IV confirm our main findings from the univariate tests above. First, capital markets distinguish among firms based on the existence as well as the magnitude of an insurer's loss exposure. Thus, EXPOSED (a dummy variable which equals 1 if the insurer has positive homeowners' premium earned in the affected state (and 0 otherwise)) and EXPOSURE (the ratio of homeowners' premium earned in the affected state(s) to total homeowners' premium earned (%)) both enter with a negative and statistically significant coefficients at the 1%-level.[*] This is consistent with arguments that investors devalue those insurers in the aftermath of catastrophe events which face potential reimbursements paid to policyholders and that higher loss exposures (which are associated with higher depletions of internal capital) lead to less favourable stock price performance around a mega-catastrophe. Second, LOWCOMPETITION enters the regression models with a positive and statistically significant coefficient (at the 1%-level) which shows that firms are more likely to benefit from mega-catastrophes when they write homeowners' insurance in the least competitive states. This is consistent with the argument that firms can more easily increase premiums in response to mega-catastrophes in states with lower competition as compared to states with higher competition where premium increases are likely to result in a permanent loss of market share.

In addition to our results at the univariate level we find further variables which significantly impact on the stock price response of insurers. TOBQ (Tobin's Q measured as

[*] We do not simultaneously include EXPOSED and EXPOSURE in one model as we find a high correlation between them.

the market value of equity plus the book value of liabilities divided by the book value of assets), for example, is negatively related with abnormal returns at the 5% level. We argue that loss events, such as mega-catastrophes, which lead to internal capital depletion are more severe for firms with strong growth prospects than for firms whose market value is more dependent on assets in place. That is because capital for new investments is more important for growth-orientated firms.

[Table IV near here]

Also, we report a negative relationship (at the 5% level) between the amount of first insured loss estimates (CATSIZE) and insurers' stock price reaction. This result was anticipated, as more expensive catastrophes (in terms of insured losses) lead to higher loss payments. Finally, we report that mega-catastrophes which are caused by hurricanes as well as catastrophes which occurred after Hurricane Katrina have positive value implications for insurers. Thus, both HURRICANE and POSTKATRINA are positive and statistically significant (at the 5%-level and 1%-level, respectively). This is in line with the arguments that the risk models for hurricanes are amongst the most advanced and most accurate (as regards the estimation of the probability of potential losses of future hurricanes) and that Hurricane Katrina caused the insurance industry to upwardly revise its expectations regarding the potential magnitude of all natural disaster losses (and not only windstorm events) which resulted in a smaller 'shock effect' for mega-catastrophes following Katrina as large-scaled losses by natural catastrophes were anticipated by capital markets (Cummins and Lewis, 2003).

To check the above results we undertake a number of additional tests. Due to space limitations we do not report the tables here but they are available from the authors upon request. First, we assess whether our results are sensitive to the event window used. For this purpose, we re-run our analysis of market-adjusted mean cumulative abnormal return using [0,+1], [0,+5] [0,+10] and [0,+20] days relative to the catastrophe event date as event windows. The results of this test show that all event windows confirm our main conclusions as the regression results remain qualitatively unaffected. Next, we examine the stability of our results after excluding Hurricane Katrina from our sample of mega-catastrophes. We do so, because Hurricane Katrina is the most expensive natural catastrophe in insurance history (in terms of insured losses) which may influence the results we report. The results show that all the main conclusions remain unaffected.

5 SUMMARY AND CONCLUSIONS

In this paper we examine a cross-section of 19 mega-catastrophes between 1996 and 2010 to shed light on two questions: first, what are the expected performance effects of mega-catastrophes on insurance firms, and second, do different types of mega-catastrophe have different impacts on insurance firm performance? Both questions have important consequences for the ability of insurance firms to protect citizens and governments from the losses caused by catastrophe events and to form part of broader national strategies to deal with the increasing risks and costs of catastrophe.

In terms of the first question our results show that mega-catastrophe have negative performance implications for insurers. However, the magnitude of share price losses during the examination period is moderate on average. We interpret this as evidence that the expected performance implications of mega-catastrophes are by no means devastating for insurers. This has important implications for the viability of insurance as a robust risk-sharing mechanism because it demonstrates that insurers are in a position to absorb the losses caused by mega-catastrophes (1) and that mega-catastrophes do not threaten the solvency of insurers.

Regarding the second question, the results show that the returns of insurers suffer more the greater the exposure to a mega-catastrophe and the higher the competition amongst insurers (the latter precludes insurers from increasing premiums to offset the underwriting losses associated with a mega-catastrophe). In addition, the results indicate that insurance firms are better able to cope with hurricane mega-catastrophes and that they have adjusted their models post Hurricane Katrina. These results are in line with the arguments that the risk models for hurricanes are amongst the most advanced and that Hurricane Katrina caused the insurance industry to upwardly revise its expectations regarding the potential magnitude of all natural disaster losses.(11)

While our results are based on U.S. insurers only (and it remains to be tested whether similar results hold for non-U.S. insurers), they provide evidence that insurers are in a position to absorb the losses caused by mega-catastrophes and that mega-catastrophes do not threaten the solvency of insurers. This implies that insurance is an effective mechanism to channel catastrophe losses away from households and governments. This result is also important given that climate change is likely to make the insurance sector subject to heightened exposure to weather-related perils and insurance can play a key role in helping (along with better risk assessment, risk perception, risk management and disaster response) to alleviate the negative impact of climate change for households and governments (1).

Three important policy implications derive from our work and focus on what policymakers can do to increase the supply of insurance as an effective risk-sharing mechanism. First, in a number of countries governments engage in the provision of insurance to households where catastrophe losses are deemed uninsurable alongside private insurers.[1, 4, 7] While our study has little to say about the adequacy or effects of the public provision of insurance, they show that private insurance firms are coping well with mega-catastrophes and justifies cautious optimism as regards the viability of private insurance helping to meet the costs associated with catastrophe. Private insurance is desirable, because it is widely seen as more economically efficient than public insurance. For instance, private insurance rewards behavior which lowers the economic costs of a peril (via lower premiums) when, say, policyholders make their property more catastrophe-proof.[6] While not directly tied to the results presented here, the private insurance industry may also have the processing capacity to help governments with broader catastrophe solutions. For example, the administrative resources of the private insurance sector could provide a platform for servicing government funded disaster recovery schemes through the marketing of policies, the collection of premiums, loss adjusting and the payment of claims.

Nonetheless, given that private insurance should only ever be seen as part of a broader disaster resilience strategy and should not be construed as a panacea, there is a need for further work in this domain. More specifically, while private insurance can help to finance catastrophe losses, recovery and construction, and provide incentives for reducing risk, it needs to be recognised that insurance could also provide disincentives. Insurance has the potential to convey a feeling of security while leaving people overly exposed to the impacts of disaster. More research on the risk behaviour effects of catastrophe insurance on individuals, corporations and governments could, therefore, prove very useful.

Second, our results challenge the appropriateness of regulatory initiatives (such as the NAIC's Solvency Modernization Initiative or Solvency II) that require insurance firms to hold substantially higher capital reserves in order to remain solvent following a catastrophe event. While the results reported in this paper have little to say about the desirability of higher capital holdings against other types of underwriting risk, they show that the expected financial losses linked to natural catastrophes for U.S. insurers do not appear to be of a magnitude to justify substantially higher capital holdings against catastrophe underwriting risk.

Third, there is a trade-off between competition in local insurance markets and how damaging catastrophe losses are to insurance firms. We show that in less competitive markets where insurers should be able to increase premium income in the years following a catastrophe event, the expected performance losses following a catastrophe event are lower. Therefore, trade-offs between competition (and by extension consumer welfare which should increase with competition and falling insurance premiums) need to be carefully balanced with an insurer's ability to profitably manage catastrophe risks. Our results suggest that less competition in local insurance markets makes insurance a more viable risk-sharing mechanism.

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Table I

Sample of Mega-catastrophes during 1996-2010

Panel A: Mega-catastrophe Characteristics

DATE	PERIL	STATES AFFECTED	FIRST INSURED LOSS ESTIMATE (MILLIONS USD)
25.08.2005	HURRICANE KATRINA	AL, FL, GA, LA, MS, TN	38,360
13.08.2004	HURRICANE CHARLEY	FL, NC, SC	7,850
24.10.2005	HURRICANE WILMA	FL	6,809
20.09.2005	HURRICANE RITA	AL, AR, FL, LA, MS, TN, TX	5,243
25.10.2003	WILDLAND FIRE	CA	2,412
05.09.1996	HURRICANE FRAN	MD, NC, OH, PA, SC, VA, WV	2,224
03.05.1999	WIND/THUNDERSTORM EVENT	AL, AR, FL, GA, IL, IN, KS, KY, LA, MO, MS, NC, NE, OH, OK, SC, TN, TX	1,944
02.05.2003	WIND/THUNDERSTORM EVENT	AL, AR, CO, GA, IA, IL, IN, KS, KY, MO, MS, NC, NE, OH, OK, SC, SD, TN	1,837
14.09.1999	HURRICANE FLOYD	CT, DE, FL, GA, MA, MD, ME, NC, NH, NJ, NY, PA, RI, SC, VA, VT	1,734
05.06.2001	TROPICAL STORM ALLISON	FL, LA, MS, NJ, PA, TX	1,502
04.04.2003	WINTER STORM	AL, IL, IN, LA, MI, MO, MS, NY, TN, TX	1,440
18.09.2003	HURRICANE ISABEL	DE, MD, NC, NJ, NY, PA, VA, WV	1,387
21.10.2007	WILDLAND FIRE	CA	1,262
12.05.2010	WIND/THUNDERSTORM EVENT	IL, MD, OK, PA, TX	1,065
31.01.1996	WINTER STORM	AL, AR, CT, DE, FL, GA, IA, IL, IN, KS, KY, LA, MA, MD, MI, MN, MO, MS, NC, NE, NJ, NY, OH, OK, PA, SC, TN, TX, VA, WI, WV	1,021
01.01.1999	WINTER STORM	AL, AR, CT, DE, FL, GA, IL, IN, LA, MA, MD, ME, MO, MS, NC, NJ, NY, OH, OK, PA, RI, SC, TN, TX, VA, WV	1,014
13.04.2007	WIND/THUNDERSTORM EVENT	CT, DE, GA, LA, MA, MD, ME, MS, NC, NH, NJ, NY, PA, RI, SC, TX, VA, VT	1,013
09.07.2005	HURRICANE DENNIS	AL, FL, GA, MS	1,005
21.09.1998	HURRICANE GEORGES	AL, FL, LA, MS	1,003

Panel B: Total Number of Mega-catastrophes broken down by State, 1996-2010

State	Events	State	Events	State	Events	State	Event	State	Events
AK	-	HI	-	ME	3	NJ	6	SD	1
AL	9	IA	3	MI	2	NM	-	TN	7
AR	5	ID	-	MN	1	NV	-	TX	8
AZ	-	IL	6	MO	5	NY	6	UT	-
CA	2	IN	4	MS	11	OH	5	VA	6
CO	1	KS	3	MT	-	OK	5	VT	2
CT	4	KY	3	NC	9	OR	-	WA	-
DE	5	LA	8	ND	-	PA	9	WI	1
FL	11	MA	4	NE	3	RI	3	WV	4
GA	9	MD	7	NH	2	SC	8	WY	-

Notes: The sample consists of nearly all US natural catastrophes during 1996 to 2010 with first insured loss estimates exceeding 1 billion USD (mega-catastrophes). According to the Property Claim Services (PCS) database this sample of mega-catastrophes makes up nearly 40 percent of total first insured loss estimates during 1996 to 2010. Insured losses are in constant 2010-USD terms based on the Consumer Price Index (All Urban Consumers). For an explanation of state abbreviations refer to Appendix Table A.I. Source: Property Claim Services (PCS).

Table II

Cumulative Abnormal Returns for Selected Event Windows

Event window (days)	N	mean (%) (t-stat)	median (%) (z-stat)	CAR<0% N	CAR<0% %
CAR[-5,-1]	716	-0.179 (-1.154)	-0.422 (-1.112)	398	55.6
CAR[0,+1]	716	**-0.279***** **(-2.840)**	**-0.401***** **(-5.050)**	419	58.5
CAR[0,+5]	716	**-0.671***** **(-3.723)**	**-0.686***** **(-4.411)**	413	57.7
CAR[0,+10]	716	**-1.105***** **(-4.539)**	**-0.930***** **(-5.035)**	414	57.8
CAR[0,+15]	716	**-1.161***** **(-3.532)**	**-0.698***** **(-3.604)**	394	55.0
CAR[0,+20]	716	**-1.393***** **(-3.777)**	**-1.292***** **(-4.037)**	408	57.0

Notes: The table reports cumulative abnormal returns (CAR) for different event windows before and after the catastrophe event date for the period 1996 to 2010. Abnormal returns are estimated using an adjusted market model:

$$AR_{it} = R_{it} - R_{mt}$$

where R_{it} is the observed arithmetic return for firm i at day t and R_{mt} is the CRSP equally-weighted market index return for day t. Also included are t-statistics (two tailed) and the non-parametric Mann–Whitney–Wilcoxon Z-scores. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table III
Summary Statistics

	Variable	Definition	N	Mean	Median	Std. Dev	1 Pctile	99 Pctile
Value effect	CAR[0,+15]	Market-adjusted mean cumulative abnormal return over [0,+15] days relative to the mega-catastrophe event date (%)	716	-1.161	-0.698	8.796	-25.905	25.049
Insurer characteristics	FIRMSIZE	Log of total assets (millions of USD)	716	8.656	8.566	2.025	5.175	13.500
	TOBQ	Tobin’s Q measured as the market value of equity plus the book value of liabilities divided by the book value of assets	716	1.103	1.049	0.229	0.689	1.955
	ROA	The ratio of pre-tax profits to total assets (%)	716	1.047	0.879	1.628	-2.721	4.407
	LOSSRATIO	Log of loss ratio which is defined as losses incurred to premiums earned in the homeowners‘ line of business	716	4.161	4.107	0.932	3.377	7.158
	EXPOSURE	The ratio of homeowners’ premium earned in the affected state(s) to total homeowners’ premium earned (%)	716	29.707	14.749	34.165	0.000	100.000
	EXPOSED	Dummy which equals 1 if the insurer has positive homeowners’ premium earned in the affected state (and 0 otherwise)	716	0.779	1.000	0.415	0.000	1.000
	LOWCOMPETITION	Dummy which equals 1 if the insurer is located in the lowest quartile of our competition measure defined as 1-Herfindahl index by state-level homeowners’ premium earned multiplied by the individual insurer’s proportion of homeowners’ insurance premiums earned in the state to nationwide direct earned homeowner premiums in the year the catastrophe struck	716	0.259	0.000	0.438	0.000	1.000
	HIGHRATING	Dummy which equals 1 if the insurer’s financial rating assigned by Standard & Poor’s is AA or better (and 0 otherwise)	716	0.056	0.000	0.229	0.000	1.000
	LINEDIVERS	A measure of line diversification defined as 1-Herfindahl index by line of business which is calculated as the sum of the squared percentage of insurance premium earned in each business line to the total premium earned in all property-liability lines (%)	716	74.622	79.463	12.625	36.641	89.214
Catastrophe characteristics	POSTKATRINA	Dummy which equals 1 if the catastrophe took place after hurricane Katrina (and 0 otherwise)	716	0.208	0.000	0.406	0.000	1.000
	relCATSIZE	The ratio of first insured loss estimate to total liabilities (%)	716	14.901	0.545	193.696	0.003	93.310
	CATSIZE	Log of first insured loss estimate (millions of USD) in constant 2010-USD terms based on the Consumer Price Index (All Urban Consumers)	716	0.743	0.407	0.917	0.003	3.647
	HURRICANE	Dummy which equals 1 if the catastrophe is a hurricane (and 0 otherwise)	716	0.474	0.000	0.499	0.000	1.000

Notes: Accounting data (apart from premium income data) refer to one fiscal quarter prior to the catastrophe event date and are from COMPUSTAT. Premium income data refer to the fiscal year of the catastrophe event and are from the State Pages of insurers’ annual filings with the National Association of Insurance Commissioners (NAIC). Loss estimates are compiled using data from Property Claim Services (PCS).

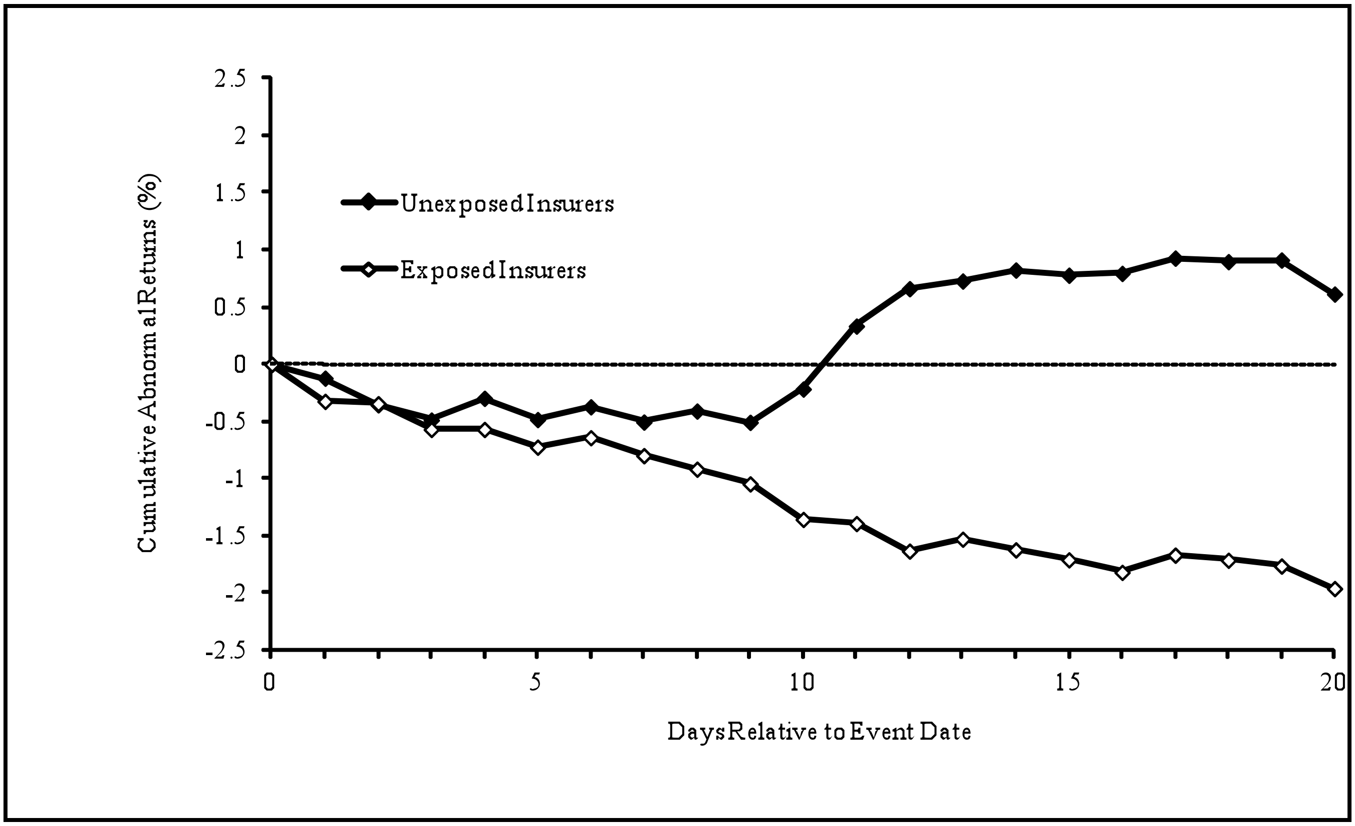
Table IV

Regressions on Insurers' Cumulative Abnormal Returns [0,+15], All Sample Insurers

	(A)	(B)	(C)	(D)	(E)	(F)
FIRMSIZE	-0.109	-0.102	-0.231	-0.110	-0.062	-0.178
	(0.11)	(0.10)	(0.23)	(0.11)	(0.06)	(0.17)
TOBQ	**-8.109****	**-8.185****	**-8.065****	**-7.547****	**-7.567****	**-7.611****
	(2.35)	**(2.31)**	**(2.39)**	**(2.21)**	**(2.15)**	**(2.24)**
ROA	1.036	1.035	0.912	1.038	1.030	0.940
	(1.42)	(1.41)	(1.23)	(1.42)	(1.39)	(1.26)
LOSSRATIO	0.073	0.099	0.096	0.143	0.158	0.141
	(0.27)	(0.33)	(0.32)	(0.52)	(0.52)	(0.46)
EXPOSURE				**-0.043*****	**-0.045*****	**-0.039*****
				(3.52)	**(3.69)**	**(3.13)**
EXPOSED	**-3.267*****	**-3.455*****	**-3.248*****			
	(3.43)	**(3.65)**	**(3.48)**			
LOWCOMPETITION	**4.999*****	**5.826*****	**7.157*****	**4.862*****	**5.793*****	**6.799*****
	(5.88)	**(5.64)**	**(6.59)**	**(5.69)**	**(5.56)**	**(6.20)**
HIGHRATING		0.034	0.032		0.014	0.014
		(0.43)	(0.40)		(0.18)	(0.17)
LINEDIVERS			4.051			4.377
			(1.35)			(1.51)
POSTKATRINA	**9.222*****	**9.886*****	**10.755*****	**9.335*****	**10.088*****	**10.769*****
	(6.63)	**(6.86)**	**(7.36)**	**(6.75)**	**(7.02)**	**(7.39)**
relCATSIZE	-0.253	-0.241	-0.198	-0.277	-0.253	-0.217
	(0.45)	(0.42)	(0.35)	(0.49)	(0.44)	(0.38)
CATSIZE		**-0.960****	**-1.427*****		**-1.089****	**-1.413*****
		(2.11)	**(3.11)**		**(2.42)**	**(3.11)**
HURRICANE			**3.226*****			**2.512****
			(3.07)			**(2.34)**
Intercept	12.490	10.736	10.013	11.894	11.242	10.485
	(1.53)	(1.16)	(1.09)	(1.45)	(1.20)	(1.12)
Observations	716	716	716	716	716	716
Year fixed effects	YES	YES	YES	YES	YES	YES
Insurer fixed effects	YES	YES	YES	YES	YES	YES
Adjusted R^2	0.196	0.198	0.210	0.201	0.203	0.210

Notes: The table reports the results of OLS regression with robust standard errors for CAR [0,+15] relative to the mega-catastrophe event. The independent variables are the log of total assets (FIRMSIZE), the insurers' Tobin's Q (TOBQ) measured as the market value of equity plus the book value of liabilities divided by the book value of assets, the ratio of pre-tax profits to total assets (ROA), the log of the loss ratio which is defined as losses incurred to premiums earned in the homeowners' line of business (LOSSRATIO), the ratio of homeowners' premium earned in affected state(s) to total homeowners' premium earned (EXPOSURE), a dummy which equals 1 if the insurer has positive homeowners' premium earned in the affected states (EXPOSED), a dummy which equals 1 if the insurer is located in the lowest quartile of our competition measure defined by 1-Herfindahl index by state-level homeowners' premium (LOWCOMPETITION), 1-Herfindahl index by line of business (LINEDIVERS) which is calculated as the sum of the squared percentage of insurance premium earned in each business line to the total premium earned in all property and-liability lines, a dummy which equals 1 if the insurer's financial rating assigned by Standard &Poor's is AA or better (HIGHRATING), a dummy which equals 1 if the catastrophe took place after hurricane Katrina (POSTKATRINA), the ratio of total insured loss to total liabilities (relCATSIZE), the total insured loss (billions USD) in constant 2010-USD terms based on the Consumer Price Index (CATSIZE) and a dummy which is equal to one if the mega-catastrophe is a hurricane (HURRICANE). Accounting data (apart from premium income data) refer to one fiscal quarter prior to the catastrophe event and are from COMPUSTAT. Premium income data refer to the current fiscal year of the catastrophe event and are from the State Pages of insurers' annual filings with the National Association of Insurance Commissioners (NAIC). Loss estimates are compiled using data from Property Claim Services. The *t*-statistics (two tailed) of the coefficients are reported in the parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Figure 1
Value Effects by Existence of Loss Exposure



Notes: The figure shows market adjusted cumulative abnormal returns (CAR) for both unexposed and exposed insurers for the 20 days following a mega-catastrophe. Exposed insurers are firms which have positive premiums earned in the homeowners' line of business in the state(s) affected by our sample catastrophes. Unexposed insurers are also firms which have positive premiums earned in the homeowners' line of business but only in the state(s) which are not affected by our sample catastrophes. Source: National Association of Insurance Commissioners (NAIC).

Appendix

Table A.I
Explanation of State Abbreviations

AK	Alaska	LA	Louisiana	OH	Ohio
AL	Alabama	MA	Massachusetts	OK	Oklahoma
AR	Arkansas	MD	Maryland	OR	Oregon
AZ	Arizona	ME	Maine	PA	Pennsylvania
CA	California	MI	Michigan	RI	Rhode Island
CO	Colorado	MN	Minnesota	SC	South Carolina
CT	Connecticut	MO	Missouri	SD	South Dakota
DE	Delaware	MS	Mississippi	TN	Tennessee
FL	Florida	MT	Montana	TX	Texas
GA	Georgia	NC	North Carolina	UT	Utah
HI	Hawaii	ND	North Dakota	VA	Virginia
IA	Iowa	NE	Nebraska	VT	Vermont
ID	Idaho	NH	New Hampshire	WA	Washington
IL	Illinois	NJ	New Jersey	WI	Wisconsin
IN	Indiana	NM	New Mexico	WV	West Virginia
KS	Kansas	NV	Nevada	WY	Wyoming
KY	Kentucky	NY	New York		

Table A.II
Sample Firms – 57 in Total

21st Century Insurance Group	EMC Insurance Group	National Security Group Inc.
Ace Ltd.	Erie Indemnity	North Pointe Group
Acceptance Insurance Corp.	Everest Re Group	Ohio Casualty Insurance Group
Affirmative Insurance Holdings Inc.	Farm Family Holdings Inc.	Old Republic International Corp.
Alfa Corp.	First Acceptance Corp.	Progressive Corp. (The)
Allstate Corp. (The)	Frontier Insurance Group Inc.	Renaissance Re Holdings
Alterra Capital Holdings Group	Hallmark Financial Service Inc.	Royal and Sun Alliance
American Country Holdings	Hanover Insurance Group (The)	Safeco Corp.
American Financial Group	Harleysville Group Inc.	Safety Insurance Group
American International Group	Hartford Financial Services	Seibels Bruce Group Inc.
Argonaut Group Inc.	Homeowners Choice Inc.	Selective Insurance Group
Aspen Insurance Holdings Group	Horace Mann Educators Corp.	Tower Group Inc.
AXIS Capital Group	Kemper Corp.	Travelers Corp.
Berkshire Hathaway Inc.	Markel Corp Group	Trenwick Group Inc.
Chubb Corp.	Meadowbrook Insurance Group	United Fire and Casualty Group
Cincinnati Financial Corp.	Mercer Insurance Group Inc.	Universal Insurance Holdings Inc.
CNA Insurance Group	Merchants Group Inc.	VESTA Insurance Group
Commerce Group Inc.	Mercury General Corp.	White Mountains Insurance Group
Donegal Group Inc.	Meridian Insurance Group Inc.	W.R. Berkley Corp.

Notes: The sample consists of all publicly traded property-liability (P&L) insurers during the period 1996 to 2010 with positive premiums earned in the homeowners' line from the State Pages of insurers' annual filings with the National Association of Insurance Commissioners (NAIC) as well historical accounting and stock price information on COMPUSTAT and CRSP, respectively.

Table A.III
Cumulative Abnormal Returns by Loss Exposure

		CAR[0,+1]	CAR[0,+5]	CAR[0,+10]	CAR[0,+15]	CAR[0,+20]
Panel A: Existence of Loss Exposure (Yes/No)						
EXPOSED Insurers	mean	**-0.324*** **	**-0.724*** **	**-1.357*** **	**-1.710*** **	**-1.961*** **
N=558	(*t*-stat)	**(-2.855)**	**(-3.610)**	**(-4.768)**	**(-4.507)**	**(-4.655)**
	median	**-0.414*** **	**-0.707*** **	**-1.021*** **	**-0.993*** **	**-1.629*** **
	(*z*-stat)	**(-4.770)**	**(-4.321)**	**(-5.217)**	**(-4.575)**	**(-4.991)**
UNEXPOSED Insurers	mean	-0.121	-0.484	-0.217	0.779	0.614
N=158	(*t*-stat)	(-0.623)	(-1.186)	(-0.481)	(1.239)	(0.828)
	median	**-0.388***	-0.517	-0.411	0.052	0.202
	(*z*-stat)	**(-1.806)**	(-1.228)	(-0.883)	(0.997)	(0.886)
$\Delta CAR_{EXPOSED\text{-}UNEXPOSED}$	mean	-0.203	-0.241	**-1.140***	**-2.489*** **	**-2.575*** **
	(*t*-stat)	(-0.854)	(-0.554)	**-(1.950)**	**(-3.160)**	**(-2.911)**
	median	-0.026	-0.190	**-0.610***	**-1.045*** **	**-1.831*** **
	(*z*-stat)	(-0.856)	(-1.007)	**(-1.910)**	**(-3.039)**	**(-3.134)**
Panel B: Level of Loss Exposure (for Insurers with Some Loss Exposure)						
HIGH Exposure(Q_4)	mean	**-0.459***	**-2.073*** **	**-3.307*** **	**-4.192*** **	**-4.969*** **
N=139	(*t*-stat)	**(-1.695)**	**(-3.840)**	**(-4.586)**	**(-4.182)**	**(-4.530)**
	median	**-0.895*** **	**-1.755*** **	**-2.703*** **	**-2.994*** **	**-3.443*** **
	(*z*-stat)	**(-2.807)**	**(-4.638)**	**(-4.945)**	**(-4.661)**	**(-4.998)**
LOW Exposure(Q_1)	mean	**-0.374****	-0.247	**-0.922****	-0.376	-0.233
N=140	(*t*-stat)	**(-2.234)**	(-0.880)	**(-2.063)**	(-0.614)	(-0.330)
	median	**-0.411*** **	-0.439	**-0.913*** **	-0.493	-0.988
	(*z*-stat)	**(-2.854)**	(-1.136)	**(-2.787)**	(-1.169)	(-0.909)
$\Delta CAR_{HIGH\text{-}LOW}$	Δmean	-0.085	**-1.826*** **	**-2.385*** **	**-3.817*** **	**-4.736*** **
	(*t*-stat)	(-0.267)	**(-3.014)**	**(-2.816)**	**(-3.7546)**	**(-3.635)**
	Δmedian	-0.484	**-1.316*** **	**-1.790*** **	**-2.501*** **	**-2.455*** **
	(*z*-stat)	(-1.212)	**(-3.401)**	**(-2.735)**	**(-3.382)**	**(-3.747)**

Notes: The table reports market adjusted cumulative abnormal returns (CAR) for different event windows following our sample of mega-catastrophes by an insurer's loss exposure (defined as the ratio of homeowners' premium earned in the affected states to total homeowners' premium earned). Both the results for exposed and unexposed insurers (Panel A) as well as for exposed insurers in the highest (Q_4) and lowest (Q_1) quartile of the distribution of loss exposure are shown (Panel B). Also, the differences in CAR between exposed and unexposed firms ($\Delta CAR_{EXPOSED\text{-}UNEXPOSED}$) as well as firms in the highest and lowest quartile of the distribution of loss exposure are reported ($\Delta CAR_{HIGH\text{-}LOW}$). To test for the statistical significance of CAR, we employ a two tailed *t*-test as well as the non-parametric Mann–Whitney–Wilcoxon test. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table A.IV
Cumulative Abnormal Returns by Competition

		CAR[0,+1]	CAR[0,+5]	CAR[0,+10]	CAR[0,+15]	CAR[0,+20]
Panel A: All Insurers						
HIGH Competition (Q_4)	mean	0.017	-0.032	**-0.854***	**-1.447****	**-1.756***
N=155	(*t*-stat)	(0.085)	(-0.091)	**(-1.786)**	**(-1.975)**	**(-1.935)**
	median	-0.032	0.093	-0.302	**-1.036****	**-1.299****
	(*z*-stat)	(-0.666)	(0.372)	(-1.363)	**(-2.010)**	**(-2.158)**
LOW Competition (Q_1)	mean	-0.076	0.507	0.694	**1.188****	**0.941***
N=186	(*t*-stat)	(-0.399)	(1.385)	(1.459)	**(2.206)**	**(1.674)**
	median	**-0.366****	-0.259	0.231	**0.844***	0.364
	(*z*-stat)	**(-2.075)**	(-0.082)	(0.640)	**(1.861)**	(1.174)
$\Delta CAR_{HIGH\text{-}LOW}$	mean	0.093	-0.539	**-1.548****	**-2.635*****	**-2.697*****
	(*t*-stat)	(0.336)	(-1.054)	**(-2.277)**	**(-2.955)**	**(-2.613)**
	median	0.334	0.352	-0.533	**-1.880*****	**-1.663****
	(*z*-stat)	(0.895)	(0.361)	(-1.467)	**(-2.740)**	**(-2.436)**
Panel B: Exposed Insurers						
HIGH Competition (Q_4)	mean	**-0.199****	-0.139	**-1.217*****	**-2.380*****	**-2.851*****
N=117	(*t*-stat)	**(-2.075)**	(-1.338)	**(-2.910)**	**(-3.542)**	**(-3.557)**
	median	**-0.133****	-0.091	**-0.573****	**-1.186*****	**-1.425*****
	(*z*-stat)	**(-2.396)**	(-0.414)	**(-2.231)**	**(-3.231)**	**(-3.682)**
LOW Competition (Q_1)	mean	-0.055	0.450	0.665	1.005	0.632
N=153	(*t*-stat)	(-0.243)	(1.056)	(1.189)	(1.609)	(0.965)
	median	**-0.397***	-0.353	0.307	0.622	0.111
	(*z*-stat)	**(-1.762)**	(-0.480)	(0.396)	(1.207)	(0.236)
$\Delta CAR_{HIGH\text{-}LOW}$	mean	-0.144	-0.589	**-1.882****	**-3.385*****	**-3.483*****
	(*t*-stat)	(-0.443)	(-1.043)	**(-2.350)**	**(-3.332)**	**(-2.944)**
	median	0.264	0.262	**-0.880***	**-1.808*****	**-1.536****
	(*z*-stat)	(0.180)	(0.451)	**(-1.690)**	**(-2.604)**	**(-2.126)**
Panel C: Unexposed Insurers						
HIGH Competition (Q_4)	mean	0.684	0.301	0.263	1.425	1.613
N=38	(*t*-stat)	(1.646)	(0.299)	(0.276)	(0.955)	(0.936)
	median	0.196	0.276	0.182	0.761	0.106
	(*z*-stat)	(1.066)	(0.558)	(0.123)	(0.036)	(-0.007)
LOW Competition (Q_1)	mean	-0.174	0.773	0.829	**2.035****	**2.374****
N=33	(*t*-stat)	(-0.784)	(1.276)	(1.185)	**(2.237)**	**(2.662)**
	median	-0.264	0.408	0.080	**2.536****	**2.852****
	(*z*-stat)	(-1.099)	(1.027)	(0.634)	**(1.974)**	**(2.332)**
$\Delta CAR_{HIGH\text{-}LOW}$	mean	**0.858***	-0.472	-0.566	-0.610	-0.761
	(*t*-stat)	**(1.744)**	(-0.387)	(-0.466)	(-0.336)	(-0.375)
	median	0.460	-0.132	0.102	-1.775	-2.746
	(*z*-stat)	(1.430)	(-0.173)	(-0.565)	(-1.280)	(-1.579)

The table reports market adjusted cumulative abnormal returns (CAR) for different event windows following our sample of mega-catastrophes by an insurer's loss exposure (defined as the ratio of homeowners' premium earned in the affected states to total homeowners' premium earned). Both the results for exposed and unexposed insurers as well as for exposed insurers in the highest (Q4) and lowest (Q1) quartiles of the distribution of competition are shown. To test for the statistical significance of CAR, we employ a two tailed t-test as well as the non-parametric Mann–Whitney–Wilcoxon test. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.